THE EFFECT OF HIGH VERSUS LOW DOSE ENDURANCE EXERCISE ON EATING BEHAVIORS IN OVERWEIGHT HEALTHY PREMENOPAUSAL WOMEN

by

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STATEMENT OF THESIS APPROVAL

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ABSTRACT

This study tested whether different doses of endurance exercise training had an effect on eating behaviors in overweight healthy premenopausal women. The effect of low dose endurance exercise (13 $kcal \cdot kg^{-1} \cdot week^{-1}$) and the effect of high dose endurance exercise (26 $kcal \cdot kg^{-1} \cdot week^{-1}$) were assessed over a 12-week exercise intervention. The aims of this study were to determine: 1) whether 12 weeks of high dose endurance training results in increased energy intake (EI) secondary to compensatory eating behaviors compared with 12 weeks of low dose endurance training; and 2) whether the high dose of endurance training leads to changes in macronutrient selection.

Twenty-four previously sedentary, overweight women, between the ages of 18 and 45 took part in a 12-week endurance exercise program (low dose: n=10 and high dose: n=14) with an ad libitum diet. Seven-day food logs were completed preexercise intervention and in the 12th week of the exercise intervention and compared for changes in energy intake and macronutrient selection. Energy expenditure was assessed via a baseline graded exercise test and VO_2 peak; exercise heart rate was regressed against exercise energy expenditure to determine a personalized prediction equation, which allowed each participant to meet her energy expenditure goals. Body weight, body mass index (BMI), fat mass, lean mass, and waist circumference were measured at baseline and at week 12 of the exercise intervention.

Energy intake and macronutrient preferences, assessed via paired and independent samples t-tests were not statistically different from baseline to week 12 within and between groups. Neither group lost a significant amount of weight, but the high exercise group gained a significant amount of lean mass over the exercise intervention ($p \leq 0.05$). These results suggest that increases in prescribed high- or low-dose exercise energy expenditure during a 12-week period do not cause a compensatory increase in energy intake, nor does it seem to change the macronutrient preferences in overweight, previously sedentary, premenopausal women. In conclusion, future research using a larger sample size may be necessary to examine the effects of increased exercise energy expenditure on eating behaviors.

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INTRODUCTION

Background/Literature Review

The prevalence of obesity continues to rise and has reached epidemic proportions throughout the world. Although there is no worldwide definition for overweight and obesity that is sufficient for all racial and ethnic groups, in the U.S., overweight is defined as having a BMI of 25-29.9 kg/m^2, and obese is defined as having a BMI of $\geq$30 kg/m^2 (1). During the past 20 years, there has been a dramatic increase in overweight and obese individuals, especially throughout the United States. In 2009, 33 had a prevalence of obesity greater than 25%, while 9 of these states had a prevalence of obesity equal to or greater than 30% (2). Although obesity is a multifaceted problem with a number of causes, it is generally accepted that two of the primary contributors to obesity include an increase in the consumption of energy-dense foods and a paralleled decrease in physical activity levels (3).

Over the last few decades, physical activity has significantly decreased. Dramatic changes in lifestyles have created a shift from higher physical activity levels to a more sedentary existence (4). Given our technology-driven workforce that has been shifting from physically demanding manual labor to sedentary work, decreased daily caloric expenditure is inevitable for a large portion of the population (5). The U.S. Department of Health and Human services (USDHHS) established the Physical Activity Guidelines for

Americans in 2008. The guidelines recommend that all adults should avoid inactivity; for substantial health benefits adults should do at least 150 minutes a week of moderate-intensity, or 75 minutes a week of vigorous-intensity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity (6). Unfortunately, less than one-third of American adults meet this recommendation and 40% are not active at all (7).

Increasing physical activity has the potential to directly increase total energy expenditure (EE), as well as indirectly adjust energy intake (EI); however, the role that a more active lifestyle has on eating behavior and appetite control is still inconclusive. For example, in a study by Stubbs et al. (2002) six lean men were studied over a period of 7 days of increasing energy expenditure, from no activity to a high exercise level, where the individuals were exercising for 120 minutes per day (8). Increasing EE did not lead to compensation of EI over 7 days; the men showed no tendency to alter any aspect of energy or nutrient intake or feeding patterns to compensate for the increased energy expended in exercise during the high exercise level. However, total daily energy expenditure tended to decrease over time during the exercise treatment, meaning the subjects partially decreased nonexercise activity as the intensity of the exercise increased.

A number of different studies have been published examining the association between food intake and physical activity. Most studies have shown that an acute bout of exercise does not increase hunger or EI, even if the exercise is of a high intensity (9). Reviews by King et al. (10-12) on the effects of exercise regimens on appetite and EI show that in the short- to medium-term intervention studies, 19% report an increase in EI after exercise; 65% show no change and 16% show a decrease. Blundell and colleagues concluded that in the short to medium term (1-16 days), exercise can create a negative energy balance, while no significant compensatory responses in EI are seen (12).

There are a few proposed ideas as to how physical activity may influence appetite. One proposed mechanism is that physical activity may modulate the hedonic response to foods, relating to the pleasure or palatability of food (13). Physical activity could possibly alter macronutrient selection and food preferences as well (14). A study by Ambler et al. reported a significant increase in fat intake (27.6 $\pm$1.4 % to 31.5 $\pm$1.5 %) and a significant decrease in carbohydrate intake (59.8 $\pm$1.1 % to 53.3 $\pm$2.1 %) in adolescent girls after 5 weeks of aerobic exercise training consisting of a combination of running, aerobic dance, competitive sports such as basketball, and occasional weight lifting. (13). One belief is that exercise may produce a certain drive to seek particular foods as a means of replenishing short-term energy stores. King has suggested that attitudes and beliefs toward exercise (for example “exercise makes you hungry”) play a role in the potential compensatory relationship between exercise and EI (14).

There still remains a gap in the literature between acute studies and longer-term interventions demonstrating whether or not changes in macronutrient selection and food preferences occur with increases in exercise EE. The Midwest exercise trial examined the effects of 16 months of supervised aerobic exercise on macronutrient intake in overweight men and women. The researchers reported no significant differences for men or women between the exercise and control groups from baseline to 16 months in fat, carbohydrate, or protein intake expressed as grams or as percentages of total energy intake (15). Composition of the diet can be very important to study when examining weight loss. The limited research and inconsistent methodology limit conclusions and, therefore, further studies are warranted.

Weight loss as a result of increased physical activity is neither inevitable nor consistent; certain individuals experience more of an effect from increasing activity than others. The relative inefficiency of prescribed increases in physical activity on weight loss may be explained by the idea that the negative energy balance created by exercise can be partially compensated for by an increase in EI. Certain individuals seem to be more responsive, while others seem to be more resistant to the weight loss benefits of exercise (16). Bartwell et al. (2009) reported that following 7 weeks of aerobic exercise in 55 sedentary premenopausal women, changes in fat mass ranged from -5.3 to +2.1 kg. Even when exercise-induced energy expenditure and energy intake were accounted for, large variability still existed in the residual changes in fat mass (17).

The purpose of this study was to examine if high-dose endurance exercise leads to compensatory eating behaviors, ultimately increasing energy intake and/or if it leads to changes in macronutrient selection or food preferences in overweight premenopausal women following an ad libitum diet. In this study, the aims were the following:

<u>Aim 1:</u> To determine whether 12 weeks of endurance training at a dose of 26 $kcal \cdot kg^{-1} \cdot week^{-1}$ leads to compensatory eating behaviors resulting in a greater increase in EI compared with 12 weeks of endurance training at a dose of 13 $kcal \cdot kg^{-1} \cdot week^{-1}$

<u>Aim 2:</u> To determine whether the high dose of endurance training leads to changes in macronutrient selection.

We hypothesized that the high-dose endurance training group would not compensate for higher physical activity levels and that energy intake and macronutrient selection for both groups would not be statistically different than the preexercise intervention data.

METHODS

Research Design

This was an experimental study involving 24 premenopausal female participants aged 18-45 years, recruited and classified as low risk according to the American College of Sports Medicine's (ACSM) risk stratification categories for coronary artery disease (18). The exercise intervention lasted 12 weeks, and participants were randomly assigned to one of two groups using the Efron procedure in order to ensure that groups were numerically balanced. The participants either completed a low endurance exercise dose of 13 $kcal \cdot kg^{-1} \cdot week^{-1}$ or a high endurance exercise dose of 26 $kcal \cdot kg^{-1} \cdot week^{-1}$. Exercise consisted mostly of treadmill walking or jogging; however, various other activities such as stationary cycling, the elliptical machine, or the stair machine were allowed for use once a week.

Participant-Selection Criteria

The study participants were healthy, without any major signs or symptoms of cardiovascular, pulmonary, or metabolic diseases as assessed by health history and physical activity readiness questionnaires. During subsequent exercise testing, if any signs or symptoms of disease arose such as ischemia, orthopnea, dyspnea, or angina pectoris, the participants were excluded from the study (18). Only one coronary artery disease risk factor was met by meet the Surgeon General's guidelines for minimal weekly physical activity. The Surgeon General recommends that all American adults receive 30 minutes of moderate physical activity on most days of the week. Participants were overweight based on a body mass index (BMI) between 25-30 $kg \cdot m^2$.

Participants were excluded from the study if they were currently dieting or planning on dieting within the study time period, had a history of thyroid problems or used medications known to affect thyroid function, used hormonal contraceptives or had used hormonal contraceptives in the past 12 months, experienced irregular menses, had any vasomotor symptoms of perimenopause or menopause, had chronic cardiovascular, metabolic, or musculoskeletal diseases, had orthopedic problems or other contraindications to exercise, and an unwillingness to be randomized. Furthermore, participants were required to complete the 21-item restrained eating subscale of the 3-factor eating questionnaire, which has a Cronbach's α reliability coefficient of 0.93; participants were excluded if classified as highly restrained eaters. Pregnant women or women planning to become pregnant during the 12-week exercise intervention were excluded from the study, due to the fact that maximal exercise testing is contraindicated during pregnancy. If a participant unexpectedly became pregnant during the study, she was asked to withdraw from the study, as pregnancy-related weight gain and body composition changes may occur, in addition to concerns regarding fetal and maternal injury secondary to vigorous exercise.

Exercise Intervention

Participants were asked to exercise 5 days a week, therefore, daily exercise volume was expressed as a high-dose of 5.2 kcal/kg/day and a low-dose of 2.6 kcal/kg/day. The prediction equation derived from individual exercise energy expenditure and heart rate data was used along with the participants' body weight at baseline to design an individualized exercise prescription that met the daily caloric expenditure goal, while allowing day-to-day variation in exercise intensity and duration. Participants were given the option to achieve their designated exercise goal via moderate- (40-59% VO_{2peak}) or vigorous-intensity (60-84% VO_{2peak}) exercise according to the Health and Human Services physical activity recommendations (USDHHS, 2008).

The first 7 weeks of the exercise intervention were elected as a "ramp period" during which the frequency, intensity and duration of exercise was progressed as a means to build aerobic endurance and orthopedic tolerance in accordance with ACSM guidelines (ACSM, 2006). The mode of exercise consisted mostly of treadmill walking or jogging. Participants had the option to choose an alternate activity, for example, stationary cycling, elliptical machine, or stair-machine once a week (20% of all exercise sessions) to provide exercise variation.

Data Collection Methods

Individuals who initially qualified for the study were asked to report to the Human Performance Laboratory in HPER North for health screening. Before screening, study volunteers were assessed for inclusion or exclusion in the study based on assessment of height, weight, BMI, waist circumference, resting heart rate and blood pressure, and completion of three questionnaires to assess health history, physical activity readiness and restrained eating behaviors. Participants fitting the inclusion and exclusion criteria were enrolled in the study, and underwent baseline assessments of energy intake, spontaneous physical activity, and body composition. When the 12-week exercise period was complete, reassessment of participants' weight, body fat, and waist circumference was administered for comparison to baseline values.

Dietary Assessment

Participants were trained to use a 7-day food diary by master's degree students in Nutrition and asked to record everything they consumed over the following seven consecutive days. Participants were asked to provide detailed descriptions of all foods and beverages, including brand names and their method of preparation and cooking. The women were instructed not to change their diets during the food record process. For mixed dishes, the amount of each raw ingredient used in the recipe and the amount consumed by participants were asked to be recorded. Standard household measuring cups and spoons were suggested for accurate measurement whenever possible. Two-dimensional and three-dimensional portion-size measurement aids were used in the study to reduce error in quantifying portion sizes. A portion size guide was given to each participant, attached to the 7-day food log, allowing participants to reference while recording foods consumed. In the final week of exercise training (week 12), dietary intake by means of a second 7-day food record was reassessed. Seven-day food logs were entered into a nutrition analysis software program Food Processor SQL (Version 10.8.0; ESHA Inc., Salem, OR) for energy intake and macronutrient analysis.

Exercise Compliance

Participants were instructed on how to log daily exercise including, the mode, intensity, and duration performed. Furthermore, participants were taught how to monitor their exercise intensity using a Polar heart rate monitor (Polar Electro Inc., Lake Success, NY). To determine if each participant was complying with her exercise prescription, heart rate monitors were worn for an entire week at the start of training and quarterly thereafter; heart rate data were then analyzed at the end of the week. The investigator met with each participant individually on a quarterly basis to review and collect the weekly exercise logs, and to discuss the participant's training experience including progress made, orthopedic problems, and obstacles regarding adherence. Further contact was made by phone or email to assess compliance, as well as when participants had questions or concerns. During the last 5 weeks of the exercise program, participants were instructed to wear heart rate monitors that recorded average heart rate and duration in the target heart rate zone. These data were used to calculate exercise adherence as recorded energy expenditure (kcal/week) divided by prescribed energy expenditure (kcal/week), multiplied by 100.

Statistical Methods, Data Analysis and Interpretation

Mean and standard deviations were computed as descriptive statistics for each group. A paired samples t-test was used to assess the changes in the variables over the 12-week intervention period within each exercise dose group. Change scores were calculated as week 12 minus preintervention values for body weight, BMI, fat mass, lean mass and waist circumference. Week 12 minus preintervention was also calculated for energy intake in total calories per week and in average calories per day, as well as for macronutrient preferences in protein, carbohydrate, and fat in average grams per day and in percentage of the diet. An independent samples t-test was used to determine between group differences in preintervention variables. If significant differences were detected between groups at preintervention, absolute change and percent change were calculated for the given variable and another independent samples t-test was conducted. In variables without a significant difference at preexercise intervention, independent t-tests were run for between group differences at week 12 of the exercise intervention. The Statistical Package for the Social Sciences (version 18, 2009 SPSS Inc., Chicago, IL) was used for our analysis and $p \leq 0.05$ was considered significant.

RESULTS

Table 1 summarizes the participant descriptive statistics by group. The mean age of the low dose exercise group was 36.6 $\pm$ 5.9 years and the mean age for the high dose exercise group was 31.4 $\pm$ 8.3 years. At baseline, there were no significant differences between the low and high dose groups in age, BMI, waist circumference, and fat mass ($p>0.05$). At week 12 of the exercise intervention, BMI and fat mass were not significantly different between groups ($p>0.05$), but the high dose group had a significantly smaller waist circumference than the low dose group ($p=0.019$). Significant differences in weight and lean mass existed at baseline between groups ($p=0.024$ and $p=0.045$, respectively). Therefore, absolute change and percent change for weight and lean mass were calculated for both the low and high exercise groups in order to determine the treatment effect on these variables. After accounting for the absolute and percent changes for each group, the differences in weight and lean mass between groups from baseline to week 12 of the exercise intervention were not significant ($p>0.05$).

Figure 1 shows the average weekly exercise energy expenditure for the low and high dose exercise groups. The average weekly exercise energy expenditure and relative exercise energy expenditure when the subjects reached dose exercise for the low group was 983.8 $\pm$ 192.8 kcal/week and 12.3 $\pm$ 1.4 kcal/kg/week, respectively. The high dose group had significantly higher average weekly energy expenditure at dose exercise at

Table 1. Baseline characteristics for the low exercise group and high exercise group (n=24)

Variable	**Low Dose Exercise Intervention** (n=10) (mean ± SD)	**High Dose Exercise Intervention** (n=14) (mean ± SD)
Age (y)	36.6 ± 5.9	31.4 ± 8.3
Weight (kg)*	79.0 ± 7.6	71.7 ± 7.2
BMI (kg/m^2)	27.8 ± 1.5	27.2 ± 1.4
Waist Circumference (cm)	84.9 ± 3.9	81.3 ± 4.6
Fat mass (kg)	29.9 ± 5.1	26.5 ± 4.9
Lean mass (kg)*	48.9 ± 4.2	45.1 ± 4.3
*Significantly different between groups ($p \leq 0.05$)		

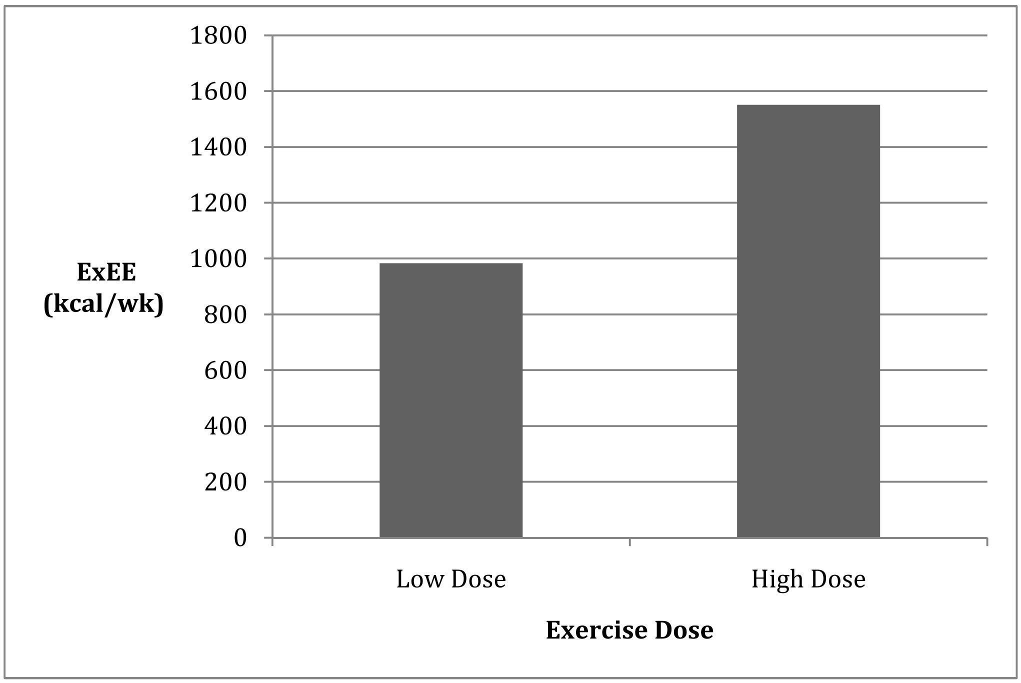

Figure 1. Average exercise energy expenditure (kcal/wk) between groups (p=0.008)

1550.6 ± 585.4 kcal/week (p=0.008) and significantly higher relative exercise energy expenditure at dose exercise at 21.2 ± 7.3 kcal/kg/week (p=0.001).

Seven-day food logs were analyzed for energy intake in total calories for seven days and average calories per day. Furthermore, they were analyzed for macronutrient selection in average grams per day of carbohydrate, protein, and fat, and in percentage of the total diet for each of the three macronutrients. Energy intake and macronutrient selection at preexercise intervention were compared to the 12th and final week of the exercise intervention. Preexercise intervention and week 12 energy intakes and macronutrient selection for both groups are presented in Tables 2 and 3. Total calories and average calories per day were not significantly different between the low and high dose exercise groups at baseline or at week 12 (p>0.05). Furthermore, macronutrient selection in average grams per day and in percentage of the diet was not statistically different between both groups at baseline or at week 12 (p>0.05).

Figure 2 summarizes the energy intake data from baseline to week 12 of the exercise intervention within groups. From baseline to week 12 there were no within group differences in mean energy intake. However, for both groups, the reported mean energy intake in total calories for the week and for calories per day was lower at week 12 compared to baseline. Calories per day from baseline to week 12 were 2016.8 ± 273.5 to 1894.5 ± 327.4 kcal and 1830.4 ± 300.1 to 1721.7 ± 333.5 kcal for the low dose and high dose groups, respectively.

Figures 3 and 4 summarize the macronutrient preferences from baseline to week 12 of the exercise intervention within groups. From baseline to week 12 there were no statistically significant within group differences in macronutrient preferences expressed

Table 2. Energy intake from preexercise intervention to week 12 of the exercise intervention in the low and high dose exercise groups

	Low Dose Exercise Group (n=10) (mean ± SD)	**High Dose Exercise Group (n=14) (mean ± SD)**
Preexercise Intervention Energy Intake		
Average calories/week (kcal)	13606.5 ± 1409.5	12698.2 ± 2233.0
Average calories/day (kcal)	2016.8 ± 273.5	1830.4 ± 300.1
Week 12 of Exercise Intervention Energy Intake		
Average calories/week (kcal)	13261.9 ± 2292.5	12052.0± 2334.4
Average calories/day (Kcal)	1894.5 ± 327.5	1721.7 ± 333.5
$p>0.05$		

Table 3. Macronutrient preferences from preexercise intervention to week 12 of the exercise intervention in the low and high dose exercise groups

	Low Dose Exercise Group (n=10) (mean ± SD)	**High Dose Exercise Group (n=14) (mean ± SD)**
Preexercise Intervention Macronutrient Preferences		
Average protein/day (grams) and percent of diet (%)	66.3 ± 17.6 (16.4 ± 6.6)	67.7 ± 9.5(16.2 ± 6.7)
Average carbohydrates/day (grams) and percent of diet (%)	263.5 ± 57.2 (46.5 ± 14.3)	245.0 ± 64.2(49.8 ± 11.3)
Average fat/day (grams) and percent of diet (%)	74.4 ± 11.1(35.0 ± 8.2)	63.8 ± 11.6 (32.0 ± 5.9)
Week 12 of Exercise Intervention Macronutrient Preferences		
Average protein/day (grams) and percent of diet (%)	72.0 ± 20.4 (16.3 ± 5.9)	63.5 ± 11.7 (16.7 ± 7.5)
Average carbohydrates/day (grams) and percent of diet (%)	238.6 ± 71.9 (43.4 ± 14.6)	221.8 ± 53.3 (48.8 ± 11.1)
Average fat/day (grams) and percent of diet (%)	73.0 ± 15.8 (37.2 ± 9.8)	64.3 ± 15.8 (33.3 ± 4.9)
$p>0.05$		

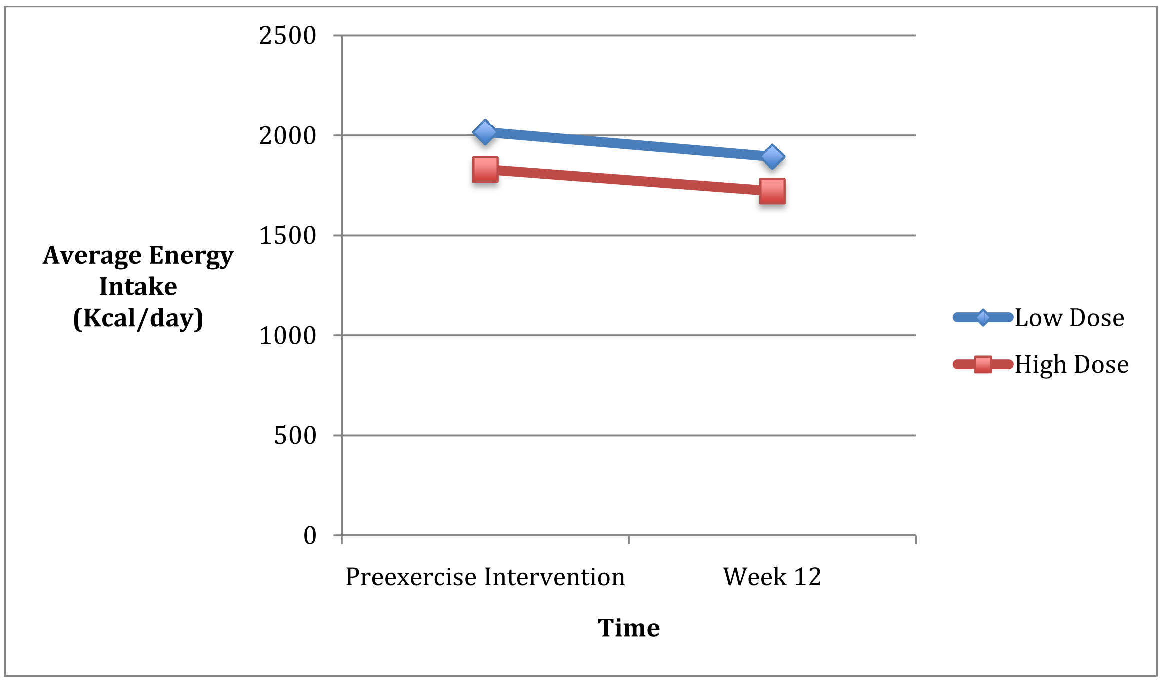

Figure 2. Preexercise intervention and week 12 energy intake (kcal/day) for the low dose and high dose groups (p>0.05)

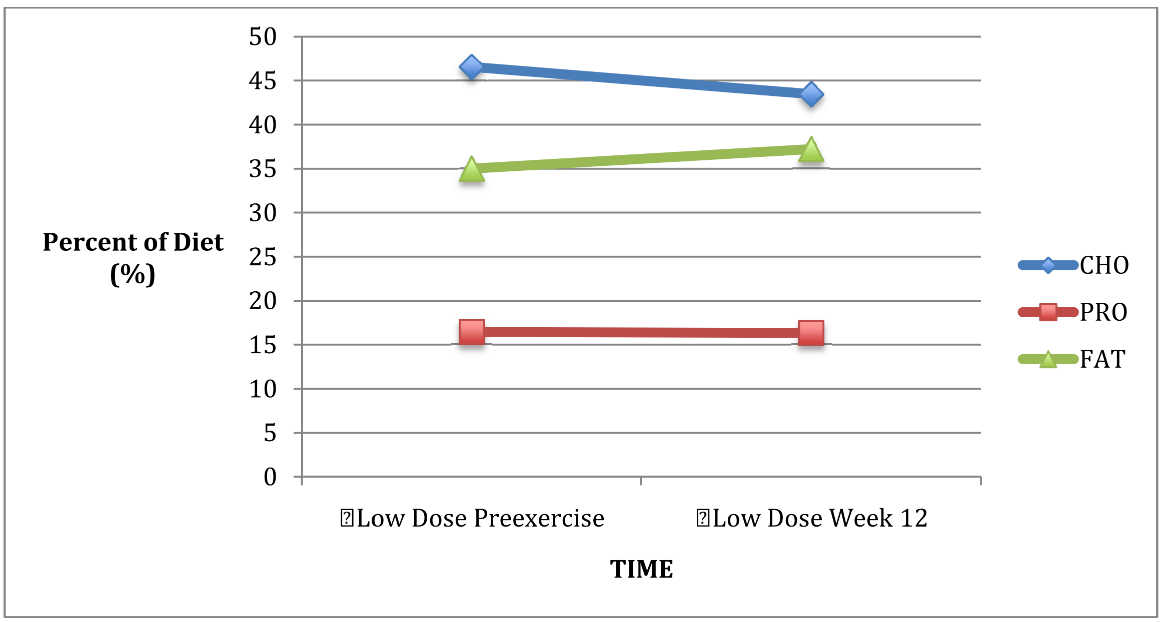

Figure 3. Preexercise intervention and week 12 macronutrient percentages of the diet (%) for the low dose exercise groups (n=10; p>0.05)

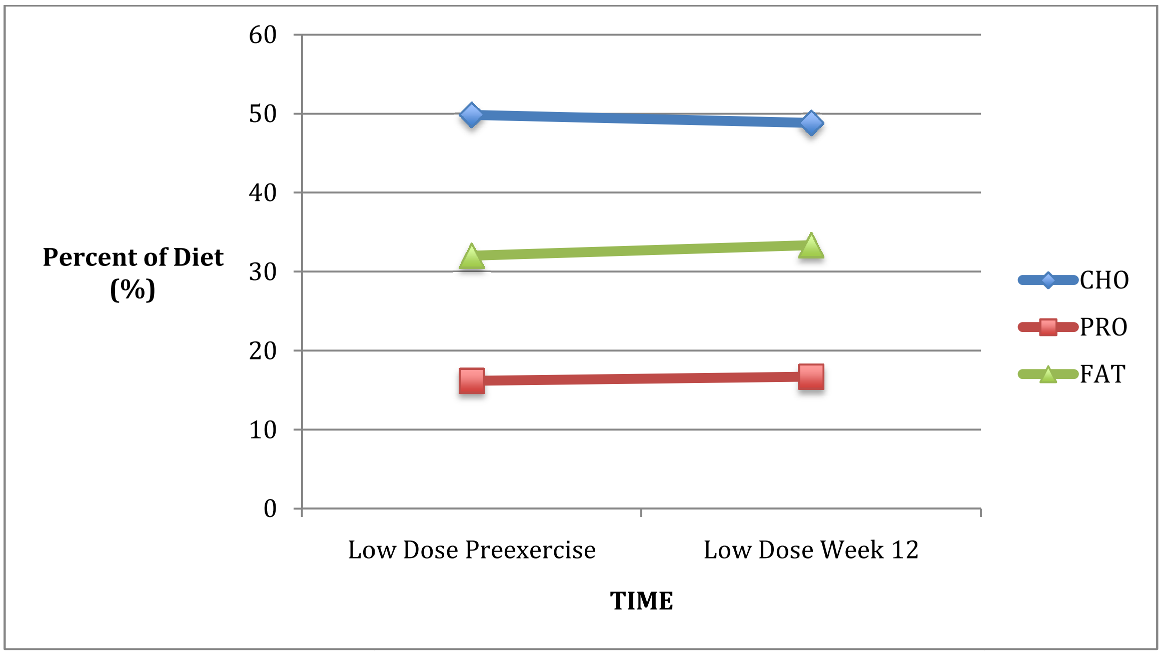

Figure 4. Preexercise intervention and week 12 macronutrient percentages (%) of the diet for the high dose exercise groups (n=14; p>0.05)

as g/day and percent of the diet. From baseline to week 12, the low dose group consumed 66.3 $\pm$ 17.6 to 72.0 $\pm$ 20.4 g protein (16.4 $\pm$ 6.6 to 16.3 $\pm$ 5.9% of the diet), 263.5 $\pm$ 57.2 to 238.6 $\pm$ 71.9 g carbohydrate (46.5 $\pm$ 14.3 to 43.4 $\pm$ 14.6% of the diet), and 74.4 $\pm$ 11.1 to 73.0 $\pm$ 15.8 g fat (35.0 $\pm$ 8.2 to 37.2 $\pm$ 9.8% of the diet). From baseline to week 12, the high dose group consumed 67.7 $\pm$ 9.5 to 63.5 $\pm$ 11.7 g protein (16.2 $\pm$ 6.7 to 16.7 $\pm$ 7.5% of the diet), 245.0 $\pm$ 64.2 to 221.8 $\pm$ 53.3 g carbohydrate (49.8 $\pm$ 11.3 to 48.8 $\pm$ 11.1% of the diet), and 63.8 $\pm$ 11.6 to 64.3 $\pm$ 15.8 g fat (32.0 $\pm$ 5.9 to 33.3 $\pm$ 4.9% of the diet).

Changes in weight do not show where the weight has changed or whether the weight loss is mostly fat, muscle or a combination of the two. Changes in body fat and lean mass were examined within both groups. The change in body fat was not statistically different across either the low or the high dose exercise intervention groups ($p>0.05$). However, changes in lean mass from baseline to week 12 were statistically significant for the high dose exercise intervention group; 45.1$\pm$ 4.3 kg at baseline to 45.8 $\pm$ 4.6 kg at week 12 ($p\leq0.05$). Figure 5 shows changes in lean mass from baseline to week 12 of the exercise intervention for low and high dose exercise groups. The low dose exercise intervention had a mean lean mass at baseline of 48.9 $\pm$ 4.2 kg to week 12 of 49.2 $\pm$ 4.3 kg, which was not a statistically significant gain ($p>0.05$).

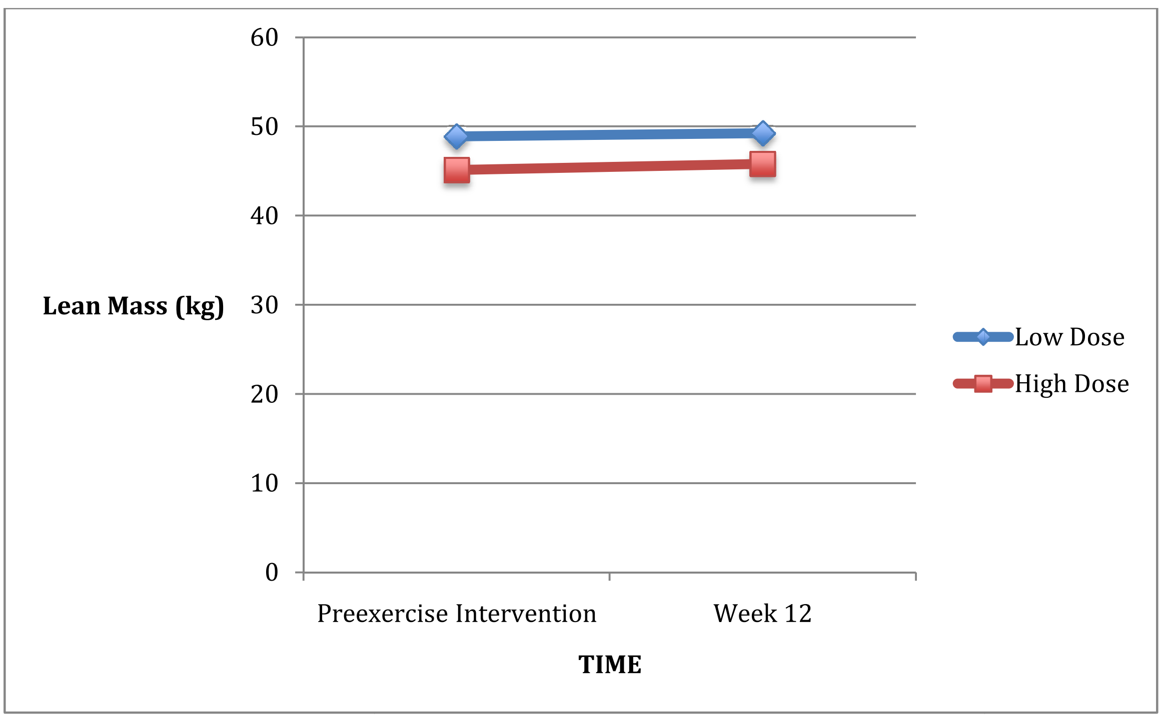

Figure 5. Lean mass changes (kg) from baseline to week 12 of the exercise intervention for low and high dose exercise groups (p>0.05 for low dose, p=0.024 for high dose)

DISCUSSION

The main purpose of this study was to examine, using a longitudinal design, the effect of a 12-week exercise intervention at two doses on eating behaviors in sedentary overweight women. Overall, neither the low dose nor the high dose12-week exercise intervention significantly changed the eating behaviors of the study participants. The results, after analyzing the 7-day food logs for energy intake from baseline to week 12 of the exercise intervention within groups, did not show a significant increase in total calories for the week or in average calories per day in either the low or the high dose groups. Also, there were no significant differences in macronutrient preferences from baseline to week 12 within or between groups. This would suggest that increasing exercise does not necessarily cause an increase in energy intake or a change in macronutrient preferences, which is consistent with a number of previous studies (8,13,19).

However, eating behavior following exercise seems to be variable among individuals, with short- to medium-term studies averaging about 7-12 weeks, showing partial energy intake compensation in some individuals, but not in all (16). And although in the present study, the mean energy intake did not increase for either the low dose or the high dose group, certain individuals had a higher energy intake in week 12 of the exercise intervention compared to baseline.

Physical activity may have the ability to improve the sensitivity of the appetite control system in humans, allowing greater dietary restraint and an improvement in the coupling of EI and EE (20). Therefore, inactivity may be linked to disrupted homeostatic mechanisms involved in appetite, which may explain why both groups had slightly higher energy intakes prior to the exercise intervention, although not significant. Previous studies by Long et al. (2002) have shown that active men have a better short-term appetite response to an unknown preload energy manipulation compared with sedentary men. The active group was able to decrease their subsequent EI, with a buffet 60 minutes following a high-energy preload, demonstrating an almost perfect compensation (90%). Therefore, these results provide indirect evidence for the beneficial role of physical activity on appetite regulation (20).

As stated earlier, previous literature has shown that weight loss induced by increased exercise energy expenditure is neither inevitable nor consistent. In the present study, the participants as a whole did not lose a significant amount of body fat in response to increasing exercise energy expenditure at two different doses, 13 $kcal \cdot kg^{-1} \cdot week^{-1}$ and 26 $kcal \cdot kg^{-1} \cdot week^{-1}$. However, body fat and waist circumference changes were correlated with exercise energy expenditure. King et al. (2008) reported large variability in the change in body weight and fat mass in 35 overweight and obese sedentary men and women after 12 weeks of supervised exercise, suggesting that individuals who experience a lower than predicted weight loss are compensating for the increase in EE (21). Contrary to this study, our findings show that the average energy intake from baseline to week 12 of the exercise intervention actually decreased for both groups; however, this reduction was not significant in either group.

Even though there was not a significant reduction in body weight, the high dose exercise group gained a significant amount of lean mass from baseline to week 12 of the exercise intervention, which might explain why this group did not lose as much body weight as would be expected after twelve weeks of an exercise intervention. The high dose exercise group gained 0.8 $\pm$ 0.3 kg (1.76 $\pm$ 0.66 lb) of lean mass. Preserving or increasing lean mass can have a number of health benefits including increasing strength, as well as basal metabolic rate (22). Furthermore, on average, the high dose group did not meet the prescribed exercise dose of 26 $kcal \cdot kg^{-1} \cdot week^{-1}$; the mean exercise energy expenditure when the high group was at dose, was 21.2 $\pm$ 7.3 $kcal \cdot kg^{-1} \cdot week^{-1}$, but this was still a significantly higher exercise energy expenditure than the low dose group (p=0.001).

The data obtained in this study demonstrate that regardless of the direction and extent of body fat changes, participants experienced health benefits from the exercise program. We found that waist circumference at week 12 was reduced in both groups from baseline, although reductions within both groups were not significant. The low dose group had an average waist circumference of 84.9 $\pm$ 3.9 cm at preexercise intervention and 84.4 $\pm$ 3.7 cm at week 12, a difference of 0.5 $\pm$ 0.2 cm. The high dose group had an average waist circumference of 81.3 $\pm$ 4.6 cm at preexercise intervention and 79.9 $\pm$ 4.7 cm at week 12, a difference of 1.4 $\pm$ 0.1 cm. At preexercise intervention, there were no significant differences between group 1 and group 2 in waist circumference; however, at week 12, the high dose exercise group had a significantly lower waist circumference than the low dose group (p=0.019). The data suggest that the high dose exercise intervention was more effective at decreasing waist circumference than the low dose group. Exercise can encourage favorable fat redistribution even under circumstances of no body fat loss. This is of great public health importance for overweight and obese individuals since increased abdominal obesity is thought to reflect visceral fat surrounding the internal organs (23). Increased visceral fat around the organs can put individuals at risk for a number of chronic diseases such as type 2 diabetes and heart disease (13).

A strength of the study was that the study participants followed an ad libitum diet, rather than receiving a predetermined test meal in a laboratory setting. Highly restrained eaters were excluded from the study, which allowed a less biased test of the true dose-response effects of exercise on body weight and energy intake. The study sample was a group that is likely to benefit from exercise training. The given exercise intensities were moderate to vigorous and in alignment with the USDHHS physical activity guidelines, which makes for good public health and clinical applicability. Furthermore, most studies examining the relationship between energy expenditure and energy intake have been limited to one exercise dose; this study examined the effects of a high- vs. low-exercise intervention (12). Participants completed 7-day food records prior to initiation of the exercise intervention, as well as the last seven days of the exercise intervention during week 12. A 7-day food record is considered the gold standard for assessing energy intake allowing intake to be assessed over the weekdays and the weekend, accounting for day-of-the week effects on nutrient intake.

A limitation of the study was that subjects were not required to weigh foods so exact amounts were not recorded. Furthermore, individuals, especially females, tend to underreport food intake when recording their diet, which can lead to an underestimation of calories consumed. With self-reported food records, individuals are often tempted to alter what they consume when recording their diet (24). The food log data were only collected during the last week of the exercise intervention therefore, energy intake data are unknown for the first 11 weeks of exercise. The sample was limited to sedentary, overweight, premenopausal women so the results cannot be generalized to other populations, although the study sample does represent a sizeable portion of U.S. women, in the age range of 18-45 years. Finally, the study sample was not as large as anticipated; 60 women planned to be recruited for the study; however, exclusion criteria were quite extensive, allowing only 24 women to meet inclusion criteria.

The goal of the exercise intervention was to determine whether there was an increase in energy intake when energy expenditure was increased; and if so, was there a dose-related response to compensation in energy intake; furthermore, to examine if the exercise intervention altered the macronutrient preferences of the study participants. The data show that compensation for increased exercise energy expenditure did not occur in either the low dose or the high dose exercise intervention groups. In fact, the mean energy intake for both groups, although not significant, decreased from baseline to week 12 of the exercise intervention. Carbohydrate, fat, and protein were also not significantly different from baseline to week 12 within or between low and high dose exercise groups.

CONCLUSION

The 12-week endurance exercise intervention, consisting of a low and a high dose was implemented to examine the effects of increased exercise energy expenditure on eating behaviors in overweight, premenopausal, previously sedentary women. The exercise intervention was unable to promote significant increases in energy intake or significant changes in individual macronutrients in either the low dose or the high dose groups. In summary, it appears that in response to energy deficits induced by exercise, both behavioral and metabolic mechanisms may be activated in order to protect against a negative energy balance. However, a negative energy balance is not generally sustainable therefore, may not be as important as a training-related increase in energy flux for long-term body composition changes and/or healthy weight maintenance. The effect of the mechanisms mentioned above is likely to differ among individuals and may explain the varying degree of resistance or susceptibility to exercised-induced weight loss. Further research is needed for a better understanding of these mechanisms, which could potentially allow more individually tailored programs to effectively prevent and treat obesity.

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